PCI Precast/Prestressed Concrete Institute

CONTINUING EDUCATION AIA

Terra Cotta-Faced Precast Concrete

PCI designer's notebook

TERRA COTTA-FACED PRECAST CONCRETE

Terra cotta tiles have been used to clad buildings in the United States for several decades, providing a distinctive aesthetic touch. Today, designers are discovering they can embed terra cotta into architectural and structural precast concrete panels as a means to more efficiently use terra cotta on projects. There are also several additional benefits, including aesthetic versatility, accelerated construction, reducing the number of joints and maintenance costs, and high thermal performance.

Figure 1a Hyatt Regency expansion, Tysons Corner, McClean, Va. All figures and photos: RTKL Associates.

Many architectural firms have used terra cotta with rainscreens on a number of overseas projects. Hand- setting the material into a traditional rainscreen application in the United States is not as economical as overseas as it leads to higher material and labor costs. A rainscreen design requires stud backing, sheathing, membrane, and aluminum extrusions (a complicated detailing process). Whereas, a terra cotta embedded precast concrete panel can achieve the same look, but provide a more cost-effective solution because of precast concrete's ability to provide multiple functions.

Figure 1b Typical precast panel elevation.

The following discussion on de-

PCI designer'snotebook

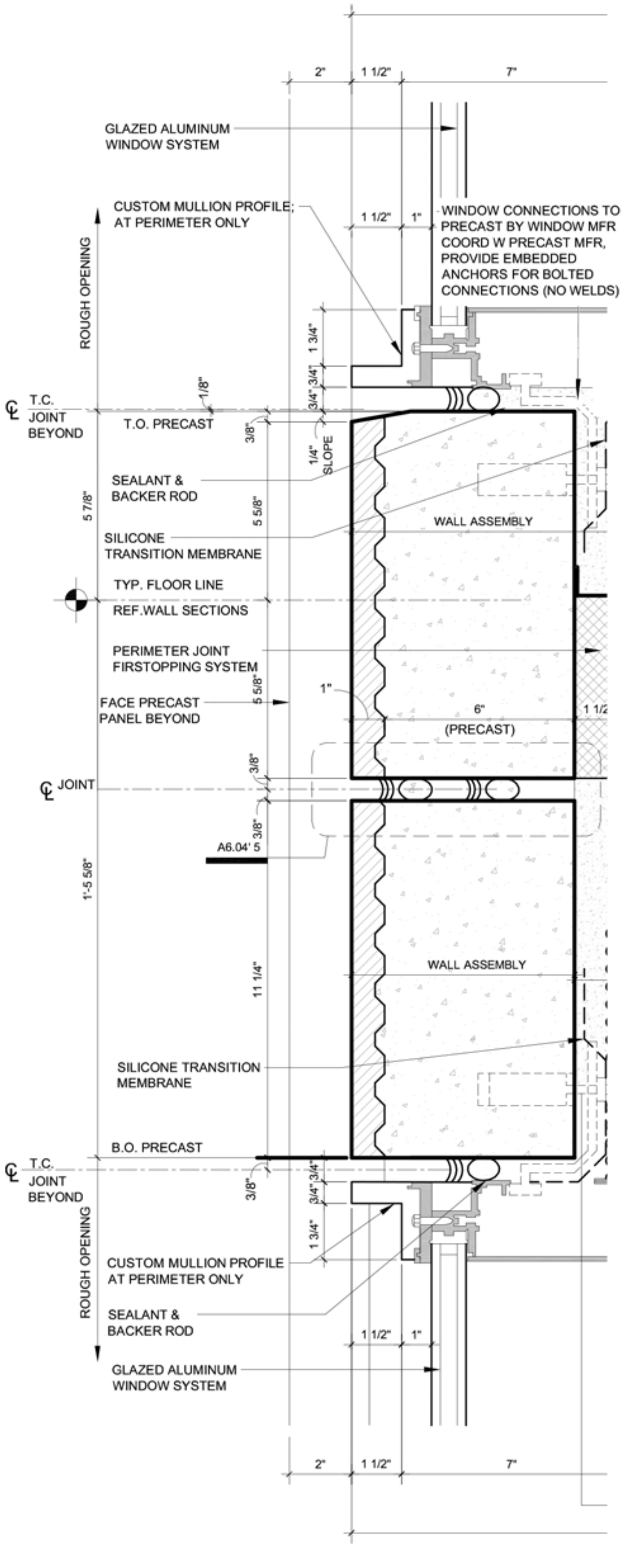


Figure 1c Wall section showing custom mullion to conceal terra cotta edge.

sign concepts and details for terra cotta cladding is taken from a presentation by Kristen Vican, RTKL Associates, Inc., Washington, D.C., on the 16-story Hyatt Regency expansion at Tysons Corner, McClean, Va, **Fig. 1a and 1b.**

Early collaboration during schematic design is key. Discussions about design concepts, such as panelization, and detailing concerns need to be addressed with the precaster and terra cotta tile manufacturer, and the plants should be visited to understand the material and fabrication restraints. Specifications should include testing and full-size-visual- mock-up requirements.

Possibly the biggest challenge involves detailing to ensure the floor-to-floor heights work with the tile dimensions to avoid having to cut the tile and leave an exposed edge. Horizontal dimensions are more critical than vertical ones, as these tiles can be more easily modified. Punched windows also must be coordinated to ensure the tile joints align. Punched windows are more challenging to do with terra cotta because of the need to cut the tile. To resolve this, the design team for the Hyatt Regency designed a custom mullion that covers the edges of panels at window openings to avoid needing returns on panels, **Fig. 1c**. It is desirable to consider window placement depth or mullion profiles to conceal edges. The concern with creating metal frames and trim is that the design still needs to allow tolerances for each material, which creates a wider gap. It is preferable to extend the edges of the precast panel past the edges of the terra cotta tiles to cover the ends.

Vertical joints should be kept shallow to minimize water infiltration behind tile at ship-lap joints. Horizontal joints are less problematic because they typically are ship-lapped, **Fig. 1d**. To ensure continuity of the terra cotta between panels without changing the joint width, joints should be the governing factor and the width at the overlap should accommodate the tile lip.

Custom tiles with finished edges and no ship-lap extension may be required between precast panels and at the top and bottom of rough openings. Angled tiles should be used at sill conditions.

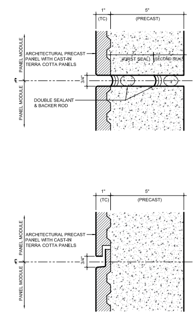


Figure 1d Typical joint and reveal at terra cotta.

Full-size mock-up panels are essential to ensure all conditions and situations are considered and reviewed prior to the start of precast erection. An aesthetic review should include the location and color of face mixes, selection of reveal depths, and selection of sealant colors. A review of patch and repair procedures also should be undertaken, including the process for replacing a full tile and for repairing minor damage, **Fig. 1e**. Tests performed on the materials, at an independent facility, should include tests for tensile bond strength (pull out tests) and freeze-thaw resistance. See PCI Specification for Embedded Architectural Terra Cotta in Precast Concrete Systems.

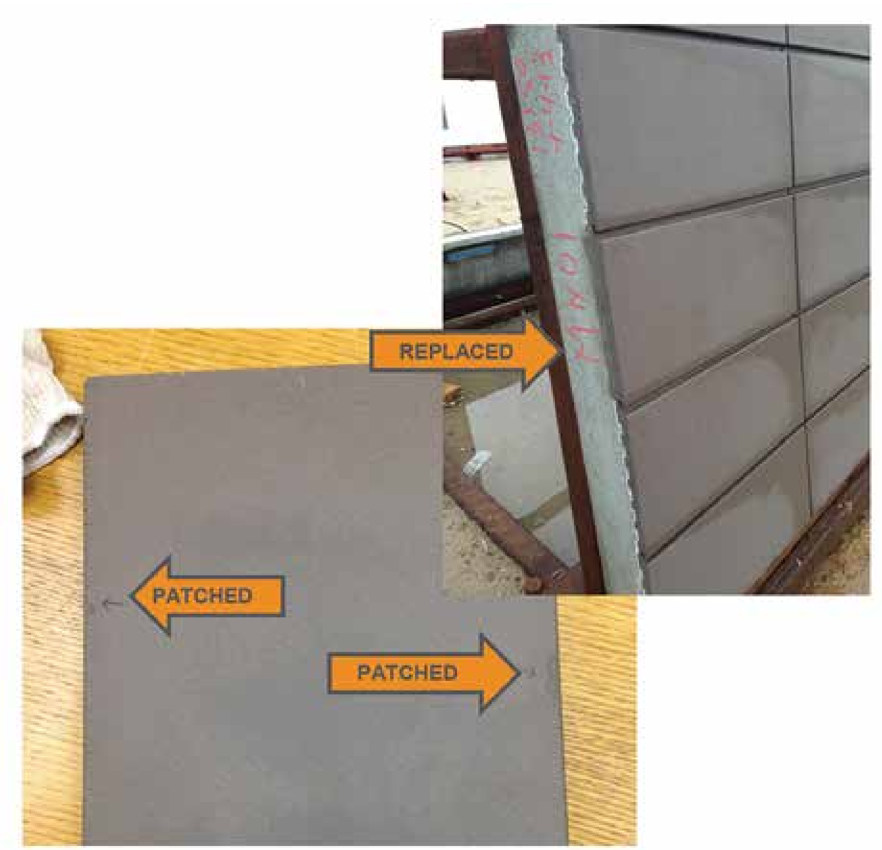


Figure 1e Patch and repair.

The objective of the PCI Specification is to outline material standards and specification criteria for terra cotta manufacturers to meet when supplying materials to precast concrete manufacturers. The intent is to establish acceptable dimensional tolerances and consistent testing standards for terra cotta embedded in precast concrete systems. The terra cotta manufacturers must confirm through the provision of independent test results that their terra cotta products comply with the PCI Specification. The PCI Specification should appear in all project specifications for terra cotta to be embedded in precast concrete. Terra cotta manufacturers have agreed to promote the compliance of their terra cotta with this specification.

The established parameters are based on the successful use of embedded terra cotta in precast concrete projects. The parameters set forth for use in this specification are attainable terra cotta properties that have been derived with input from terra cotta manufacturers, precasters, engineers, and architects, as well as consideration of existing test results.

Suggested Visual Mock-up Requirements

Erect on site, at location directed by Architect, typical prototype installation of precast concrete and terra cotta-faced precast concrete complete with adjacent building systems interfaces as shown on architect's drawings.

1. Simulate final wall conditions including joint conditions, flashings, sealants including two-stage seal conditions, anchorage, supports and other features used in final Work.
2. Construct mock-ups prior to ordering final materials and after acceptance of samples.
3. Display full, accepted color range and texture. Replace rejected panels until acceptable color range is achieved.
4. Show types of surface defects expected to be encountered, including repair procedures and workmanship. If acceptable repair procedures cannot be achieved on mock-up for specific defects and deficiencies, those defects and deficiencies shall be considered as cause for rejection of panels.
   a. Show patching for minor damage to a tile.
   b. Show replacement technique for one typical full terra cotta tile.
   c. Before commencing mock-up patching, confirm patching procedures with Architect and establish by trial mix formula for patching of finish. Demonstrate patching techniques on mock-up panels prior to actual use on any Project units.
5. Incorporate transitions to related primary materials specified in other sections per the mock-up panels described on Architect's drawings.
6. Maintain approved mock-up until completion of precast Work.

Pre-Production Sample Mock-up: Construct typical precast panels for inspection and approval at precast plant by Architect prior to full production release.

PCI Specification for Embedded Architectural Terra Cotta in Precast Concrete Systems

A. Terra Cotta Units: Thickness, not less than 3/4 in. (19 mm) nor more than 1-1/2 in. (38 mm)

1. Size- Dimensional Tolerances:

   a. Width: Plus or minus 0.039 in. (±1 mm) for any length up to 60 in. (1.5 m).

   b. Height: Plus or minus 0.0625 in. (±1.6 mm) up to 10 in. (250 mm).

      Plus or minus 0.09375 in. (±2.4 mm) up to 15 in. (380 mm).

      Plus or minus 0.125 in. (±3.2 mm) up to 20 in. (500 mm).

      Plus or minus 0.156 in. (±4 mm) up to 24 in. (0.6 m).

   c. Thickness: Plus or minus 0.0625 in. (±1.6 mm).

2. Color and Texture: **[Match Architect's approved samples]**.

   [Match existing adjacent terra cotta]

   a. **<Insert information on existing terra cotta if known>**

3. Special Shapes: Include corners, edge corners, and end edge corners.

4. Cold Water Absorption at 24 hours: Maximum 6.0% when tested in accordance with ASTM C 67.

5. Efflorescence: Rated "not effloresced" when tested in accordance with ASTM C 67.

6. Out of Square: Plus or minus 1/16 in. (±1.6 mm) when measured in accordance with ASTM C 67.

7. Warpage Tolerances:

   a. Straightness (sweep): Plus or minus 0.25% of length

   b. Diagonal Flatness: Plus or minus 0.25% of diagonal

   c. Vertical Flatness: Plus or minus 0.5% of height

8. Variation of Shape from Specified Angle: Plus or minus 1 degree.

9. Tensile Bond Strength: Not less than 150 psi (1 MPa), before and after freeze-thaw testing, when tested in accordance with modified ASTM E 488. Epoxy steel plate with welded rod on total terra cotta surface for each test.

10. Freeze-Thaw Resistance: No detectable deterioration (spalling, cracking, or chafing) after 300 cycles when tested in accordance with ASTM C 666 Method A or B.

11. Modulus of Rupture: Not less than 2000 psi (13.8 MPa) when tested in accordance with ASTM C 67.

12. Compressive Strength: Not less than 6000 psi (41.4 MPa) when tested in accordance with ASTM C 67.

13. Chemical Resistance: Rated "not affected" when tested in accordance with ASTM C 126.

14. Glaze Resistance to Crazing: Rated "not affected" when tested in accordance with ASTM C 126.

15. Back Surface: Dovetail.

B. Test sample size and configuration shall conform to the following parameters in order to validate compliance by terra cotta manufacturer with PCI Specification for use in embedded terra cotta precast concrete systems:

1. Minimum number of test specimens: Comply with appropriate specifications except for freeze-thaw and tensile bond strength tests on assembled systems.

2. Minimum number of test specimens for freeze-thaw and tensile bond strength test: Ten (10) assembled systems measuring 18 in. x 10 in. (450 mm x 250 mm) long with a 16 in. x 8 in. (400 mm x 200 mm) piece of terra cotta embedded into the concrete substrate (assembled system). Note the piece of terra cotta shall have a dovetail back surface geometry. The 10 assembled systems are divided into five Sample **A** assemblies and five Sample **B** assemblies. The precast concrete substrates shall have a minimum thickness of 2-1/2 in. (63 mm) plus an embedded maximum 1-1/2 -in. (38 mm) -thick piece of terra cotta. The precast concrete shall have a minimum compressive strength of at least 5000 psi (34.5 MPa) and 4% to 6% entrained air. The 16 in. x 8 in. (400 mm x 200 mm) embedded terra cotta piece shall be centered in the 18 in. x 10 in. (450 mm x 250 mm) sample.

The terra cotta unit from the center of each Sample **A** assembly shall be tested for tensile bond strength in accordance with Item #9. Instead of anchor specified in ASTM E488, use 3/4 in. (19mm) minimum thickness steel plate of same size as single terra cotta unit bonded with epoxy (conforming to ASTM C 881, Type IV, Grade 3) to entire terra cotta unit for each tensile bond strength test. The steel plate shall have a centrally located pull-rod welded to the plate. Each Sample **B** assembly shall first be tested for freeze-thaw resistance in accordance with Item #10 and then the terra cotta unit from the center of each Sample **B** assembly shall be tested for tensile bond strength, Item #9.

Architectural terra cotta is a custom-made product and, within certain limitations, is produced in sizes for specific jobs providing the designer with a wide range of modular designs. Most projects have used solid terra cotta tiles of 1 in. (25 mm) thickness, as designers have found this thickness provides the optimum combination of stiffness and flexibility to work with the weight and thickness of the panels. Tile manufacturers can make tiles in a range of 3/4 in. to 1-1/2 in. (19 mm to 38 mm) thick. The panels can be stiff and robust even at 3/4 in. (19 mm).

The solid tiles used with precast concrete installations typically are no longer than 5 feet (1.5 m) and between 6 inches (150 mm) and 2 feet (0.6 m) in height. Custom profile and sizes are possible. There is a wide range of color options and surface finishes that include natural, honed, wire struck, profiled, and glazed.

Terra cotta dimensional capabilities are more versatile than with thin bricks, one of the material's key attractions. It's a modular material that offers longer, linear tiles than other options. But there also are limitations, with a need to balance height and length to achieve the best structural performance.

Typical Casting Procedure

The process of embedding terra cotta into precast panels is similar to creating panels embedded with thin brick or tile, although some differences exist. Terra cotta pieces typically are placed into the panels without the formliners that are used in casting panels with thin bricks. Foam fillers and sealants are applied at the joints so the concrete does not bleed through.

Inadvertent damage to the face of the terra cotta must be avoided. Terra cotta is generally stacked as would be done with bricks but a paper layer or styrofoam is laid between each layer to protect the face until it is ready to be set into the forms. The pieces are handled more like thin stone.

Early Applications

- The 40-story office building 575 Market Street, San Francisco, Calif., completed in 1975 has 9 ft (2.7 m) wide by 13 ft (4 m) high L-shaped, terra cotta-faced precast concrete panels **Fig. 2**. Seven equal 1-3/4-in. thick (44 mm) thick terra cotta pieces were placed in a structural lightweight concrete backup in the 7-1/2-in. (190 mm))thick story high panels. Architect: Hertzka & Knowles, San Francisco, Calif.

- Built in 1906, the six-story 88 Kearney St. is considered one of San Francisco's architectural landmarks. For that reason, it was decided that the building's terra cotta façade would be preserved on an otherwise all-new structure of slightly taller height, designed by Skidmore, Owings, and Merrill. The terra cotta was taken off the building, piece by piece, and the pieces were identified for subsequent reassembly on new precast concrete panels, **Fig. 3a and 3b**. Stainless steel wires were looped through the

Figure 2 575 Market Street, San Francisco, Calif.

Figure 3a and b 88 Kearney Street, San Francisco, Calif.
Photos: Skidmore, Owings and Merrill, San Francisco.

Figure 4a Sacramento County Systems and Data Processing Building, Sacramento, Calif. Photos: HDR Architecture Inc.

back ribs of the terra cotta pieces and projected into the backup concrete to anchor the pieces to the concrete.

- Precast concrete panels with 1 in. (25 mm) -thick brick on 5 in. (125 mm) thick concrete panels along with glazed terra cotta on the spandrels and mullions clad the nine-story Sacramento County Systems and Data Processing Building, Sacramento, Calif., designed by HDR Architecture, Inc. Panels of light and deep sandblast finishes

Figure 4b Terra cotta spandrel units.

Figure 4c Terra cotta mullions.

Figure 5a 600 North Michigan Avenue, Chicago, IL.

Figure 5b Flat, fluted, and round terra cotta tiles.

tied both systems together. See **Fig. 4a, and 4b, and 4c** for a close-up of the terra cotta units.

- For the sake of the traditional look of Chicago's historic Michigan Avenue streetwall's appearance, terra cotta-faced precast concrete was used for the 260,000 ft^2 (24,200 m^2) retail/cinema building, designed by Beyer Blinder Belle, (**Fig. 5a**), encompassing an entire block. The terra cotta pieces are a variety of shapes and sizes, with some flat, fluted, or round (**Fig. 5b**). The backs of the extruded pieces were flat and holes were drilled in the terra cotta for insertion of stainless steel pins. The terra cotta units were placed in a mold and 10 in. (250 mm) of concrete was then cast to create a panelized system.

Recent Projects

Consolidated Rental Car Facility, Boston, Mass.

The ConRAC (Consolidated Rental Car Facility) at Logan International Airport in Boston, Mass., features a façade consisting of terra cotta tile panels embedded in structural precast, prestressed concrete walls. The design provides a dramatic and complementary appearance, but it posed challenges as the first use of terra cotta on structural panels in North America and one of the few in the world. The project designed by Parsons Brinckerhoff, Boston, to handle approximately 5000 vehicles consists of a four-level, 1.2-million square-foot (111,000 m^2) parking garage to consolidate rental car facilities. The three elevated levels of the structure are comprised entirely of structural precast concrete components with the exterior products enhanced by the use of various architectural finishes.

Initially, designers intended to use inset thin brick on precast concrete structural panels as the dominant material because it complemented local buildings. Officials at Massport, the owners, liked the concept but wanted a more contemporary design overall to provide a balance between the old historic neighboring houses and the modernized airport, and the use of terra cotta came to mind as being the appropriate material. The garage façade architect, Fennick McCredie Architecture, Boston, developed the terra cotta option, and a manufacturer with quarries near Florence, Italy, was selected to provide the material. The terra cotta provided the warmth and color of brick but also the modern look as it could be used in larger pieces and different sizes that appealed more than the smaller, standard brick sizes, **Fig. 6a**.

The original concept was to construct precast concrete walls for the structural needs and then provide a metal frame to serve as a rainscreen, with the terra cotta panels set into that. As they worked with the precaster, however, the construction manager and the design team realized that embedding the terra cotta into the precast panels, as more typically was done with thin bricks, could save a substantial amount of money—about $1 million in material and construction costs.

The panels were cast 51 feet (15.5 m) tall, 12 feet (3.6 m) wide, and 10-1/2 inches (266 mm) thick, with 3/4 inch (19 mm) thick terra cotta pieces set into specially manufactured formliners and the concrete cast over them, **Fig. 6b**. Four (4) basic tile sizes were utilized to achieve the desired appearance: 7″ x 1′-0 9/16″ (178 x 319 mm); 7″ x 1′-7 13/16″ (178 x 503 mm); 1′-3″ x 1′-0 9/16″ (381 x 319 mm); and 1′-3″ x 1′-7 13/16″ (381 x 503 mm). Some special tile were made for the corner conditions up to 2′-11″ (889 mm) in length. Color pigmented concrete was used to compliment the tile where it is exposed at the "grout" joints between the tiles and as an 'accent tile' at discrete locations. Haunches also had to be cast into the panels' interior sides to support three levels of double tees for the four-story building.

In addition to the terra cotta embedment into the structural wall panels pictured below, terra cotta tile were also embedded in some of the precast spandrel panels on the West façade.

Figure 6a CONRAC at Logan International Airport in Boston, Mass.

Figure 6b Close-up of terra cotta tiles. Photos: Fennick McCredie Architecture.

Prior to approving the system, a variety of prototypes and mock-ups were created to identify issues related to manufacturing, finishing, hauling, erection, maintenance and repair. Testing was performed on the terra cotta tile to verify conformance with freeze thaw, water absorption, efflorescence and thermal shock.

Small sample panels were created to guide color selection and jointing, followed by the creation of full-size prototypes. These life-size mock-ups were even driven around the plant on bumpy roads to simulate worst-case delivery conditions. Some tiles were deliberately cracked to see how easily they could be repaired or replaced, if needed. The panels worked very well and met or exceeded all of the design expectations.

Embedding the terra cotta into structural components was one of the critical factors to the design because the nine rental-car companies that will operate the structure wanted complete flexibility in laying out their spaces and directing customers through their tenant area. That required a wide-open expanse with lateral load resisting elements moved to the perimeter to eliminate interior shear walls or bracing. Precast concrete's structural versatility was the perfect solution. The structure features 60- by 60-foot (18 x 18 m) bays consisting of precast concrete columns and double tees. H-frames were used to support loads along the perimeter, with interior moment frames provided between columns and girders.

The terra cotta-faced precast concrete panels also provided a noise buffer that helps prevent noise from reverberating through the area.

Figure 7a Public Safety Building, Salt Lake City, Utah. Photos: Benjamin Lowry, GSBS Architects.

Public Safety Building, Salt Lake City, Utah

Salt Lake City officials set high standards when planning the new 172,000 square-foot (15,979 m^2) Public Safety Building. The four-story facility needed to house police and fire facilities, central dispatch, emergency operations, and a state-of-the-art media-communications center, **Fig. 7a**.

Figure 7b Insulated panels.

Figure 7c The high-performance precast concrete panels provided both energy efficiency and protection from ballistic penetration.

As the center for first responders in an emergency, the building had to protect against both natural and man-made forces that could disrupt response time. This required GSBS Architects, Salt Lake City, Utah, and MWL Architects and Planners (McClaren, Wilson & Lawrie Inc.) Phoenix, Ariz., to build in fire, blast, seismic, and other protections while also creating a welcoming facility for visitors. The high high-performance building also had to achieve high LEED standards, with a goal of becoming the first public-safety building in the country to achieve Net Zero energy use.

To help meet these needs, designers clad the building with insulated architectural precast concrete wall panels embedded with terra cotta pieces. The panels not only provided protection and energy efficiency, but also created an aesthetically pleasing appearance.

The ability of precast concrete to provide dense, thick walls offered the key to the needed ballistic protection. Designers wanted to ensure that officers were protected from drive-by shootings and other projectiles, with the building's durability intended to discourage them from being fired on in the first place. Manufactured with 7,000-psi (48.3 MPa) concrete, the panels consist of 1-3/16 inches (30 mm) of terra cotta, a 3-3/16-inch (80 mm) wythe, 2-1/2 inches (63 mm) of rigid polyisocyanurate insulation, and an interior 4-inch (100 mm) concrete wythe to complete the building's enclosure, **Fig. 7b**.

That thickness of terra cotta and concrete was designed to protect against high-caliber ballistic penetration. Tests showed that no projectile could penetrate the second layer of concrete, much less go through it.

The 9 foot- (2.7 m) tall by 30 foot- (9.1 m) long panels were connected to the columns so as to allow the panels to move with the frame, which is braced with 55 viscous seismic dampers stacked on vertical columns. The panel sizes and weights created no special challenges in connecting them to the frame.

The designer's goal was to complement the nearby historic city hall's Neo-Gothic design that featured brown sandstone. The use of terra cotta tiles embedded in the precast concrete panels allowed the creation of a dialogue between the buildings despite the difference in age.

The Old-World style of the sandstone's texture was achieved by mixing three colors of terra cotta in random patterns, creating a complementary shade to the sandstone that has a similar uneven appearance. The desired look was refined, clean, and simple, but also one that spoke to the function of the building through its durability and strength, **Fig. 7c**.

The terra cotta tiles were fired as 1-foot by 5-foot (0.3 x 1.5 m) tiles, and they were embedded into the panels to create a 30-foot (9.1 m) grid pattern. The long, narrow dimensions of the panels were large enough to make the panelization economical without requiring special connections or design considerations to provide the necessary seismic movement. The design was standardized sufficiently to keep it economical.

CityCenterDC, Washington, D.C.

Built on the site of the former Washington, D.C., Convention Center and called one of the largest urban developments on the East Coast of the United States, CityCenterDC consists of two million square feet (185,800 m^2) in six buildings over five city blocks. Designed to serve a central element in the rebirth of the city's downtown, CityCenterDC's vast development plans included two condominium buildings, two rental apartment buildings, two office buildings, a luxury hotel, and public park.

Shalom Baranes Associates, in association with Foster + Partners, was selected to design the masterplan as well as buildings of this expansive project. The site features two "trophy" office buildings with glass curtain walls and two condominium buildings of traditional precast panels and curtain walls on the outer perimeter designed by Foster + Partners. The architects from Shalom Baranes Associates wanted something distinctive for their design of the two interior buildings of the masterplan. Drawn to the texture and distinct appearance of terra cotta, the architects elected to clad the project's two largest buildings—11-story apartment buildings containing 450 residential units—in approximately 82,000 square feet (7600 m^2) of precast terra cotta panels, **Fig 8a**.

The two buildings are not identical due to the different building configurations as well as the varying floor to floor heights. The complexity of the façades is not readily apparent from the street face. The façades, although relatively tight to the street face, step down at an alley and plaza framing terraces and courtyards.

There are 1,692 precast terra cotta panels spread between the two residential buildings. These panels are composed of over 31,000 terra cotta tiles set within them. The simplicity of

Figure 8a Overview of CityCenterDC, Washington, D.C.

Figure 8b One of the two residential buildings.

the appearance of the building façades belies the fact that the panels are unique in their individual slab attachments, terminations and locations. The terra cotta tiles have several different vertical dimensions and two jointing sizes to adjust for the differences in the floor heights. In each of the panels, the terra cotta tiles are whole and uncut to allow for a uniform appearance on each of the buildings. The differences in the terra cotta tiles and jointing are cleverly hidden. The only locations where the terra cotta tiles are discernibly different are at the first floors of each building where the floor to floor heights range from 14 ft. to 30 ft. (4.2 to 9.1 m). With three colors of terra cotta tiles, the rules of the tile arrangements were established by the architect.

Figure 8c Precast panels shift from elevation to elevation.

Finding just the right combination of hues for the façade to complement the surrounding buildings in the project required fabricating terra cotta samples to match paint samples. This enabled the architect to see different color scheme mock-ups on the building at different points throughout the day and in differing weather conditions, **Fig. 8b**.

There is a complex syncopation and rhythm of the precast on the building façades with the precast shifting from elevation to elevation and not always vertically stacked through the entire height of the building. The panel "movement" required strict alignment because the window wall, curtain wall, and storefronts followed in sequence and often were placed within the terra cotta panel openings. The various window systems align vertically. In addition, the façades have continuous horizontal slab edge covers attached to the precast panels, which are also integrated in the window system.

The design team concluded that terra cotta on precast not only was cost effective, but saved significant time in a very demanding schedule. They were able to develop an urban setting that feels residential and intimate in scale and material, **Fig. 8c**.

Figure 9a University of Missouri Henry W. Bloch Executive Hall, Kansas City, Mo. Photo: Ashley Streff.

University of Missouri Henry W. Bloch Executive Hall, Kansas City, Mo.

Designers BNIM Architects/Moore Ruble Yudell Architects & Planners, Kansas City, Mo., of the University of Missouri Henry W. Bloch Executive Hall of Entrepreneurship and Innovation, Kansas City, Mo., **Fig. 9a**, wanted to create a contemporary structure that complemented the university's historic masonry.

The dappled terra cotta façade they chose is a modern take on a traditional color palette, but the use of insulated wall panels behind the terra cotta tiles makes the high-performance façade truly innovative. It was the country's first terra cotta-clad, insulated, composite precast concrete panels assembly.

In the past, terra cotta had been clad into smaller, noninsulated panels, but not on such large (12 ft wide [3.7m]) fully insulated panels. Through collaboration among all of the project teams, they were able to combine the cost and time efficiencies and thermal attributes of precast concrete insulated panels with the beauty and elegance of terra cotta tiles. An analysis of the building's enclosure showed the best approach to be two, 4-inch (100 mm) wythes of concrete sandwiched around 3 inches (75 mm) of rigid insulation. The insulation was continuous from edge to edge and top to bottom.

The cladding was originally envisioned as a conventional rainscreen system with a steel frame and an air barrier. But a cost analysis by the general contractor concluded that a traditional rain screen would cost considerably more (over 25%) than terra cotta clad insulated precast concrete panels. The casting of the 19,200 square feet (1784 m^2) of precast panels was completed in three months and the entire building envelope was erected in

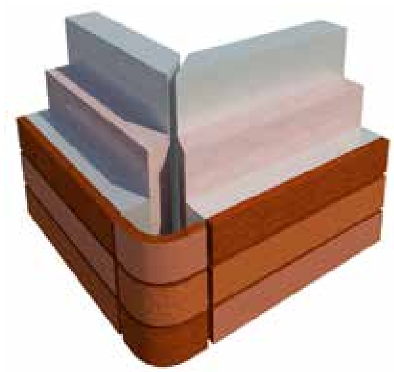
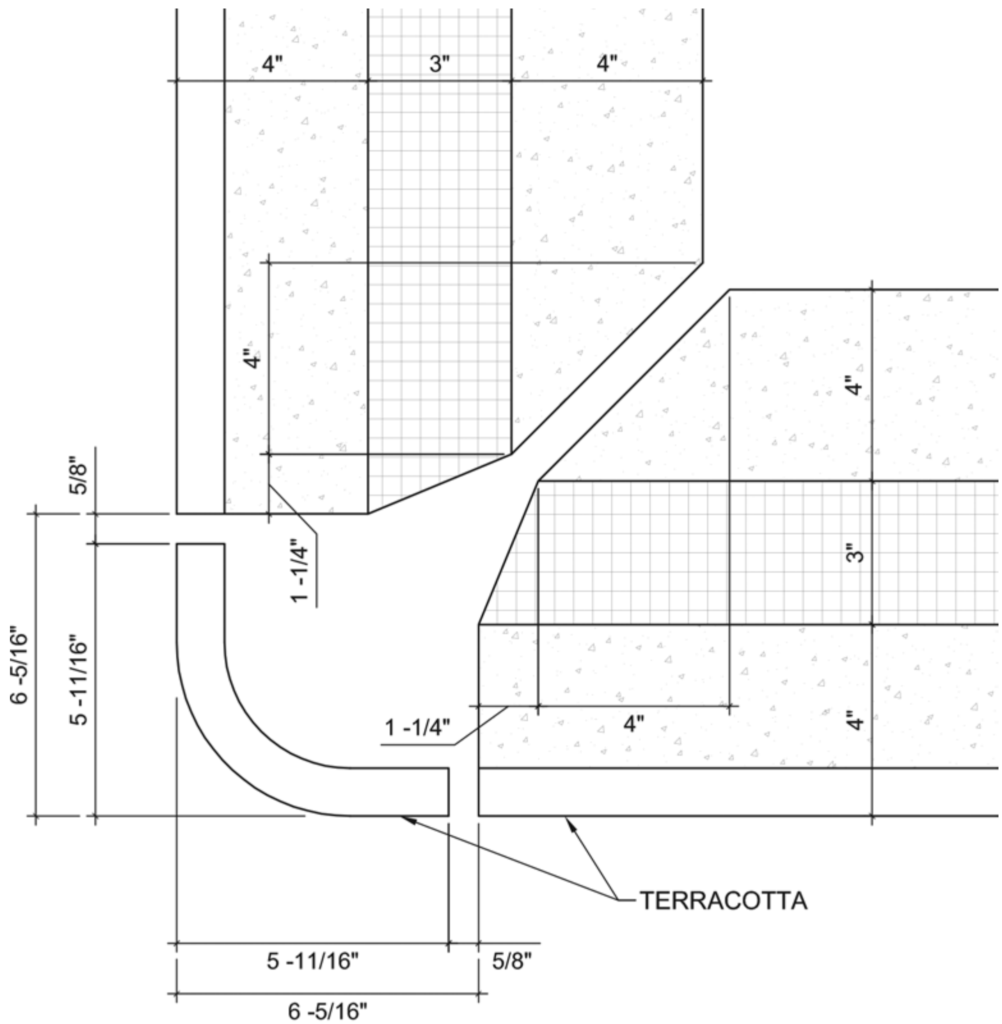


Figure 9b

Figure 9c



Figures 9b, c and d Details of miter at terra cotta clad rounded corner. Terra cotta tiles are extruded and adding a round corner to a flat tile is impractical and expensive. Therefore, a separate curved tile was produced.

Figure 9e Color of tiles to reflect nearby brick buildings.

Figure 9f Close-up of multi-colored tiles.

just 12 weeks. Carefully recessing the precast joints concealed them in a way to give the illusion of a traditional rainscreen. Precast does not show up in the joint, it is a shadow. The horizontal joint is a shiplap joint.

To ensure the terra cotta panel design would work, extensive research was conducted on the coefficient of thermal expansion, (typically 3.5 to 4.6 x 10^{-6} in./in./°F) [6.3 to 8.3 x 10^{-6} mm/mm °C], the amount of precast concrete bowing that could be tolerated without cracking the terra cotta tiles, the determination of the optimum thickness of the tile, and resistance to freezing and thawing.

The building included seven shades of terra cotta and one glazed accent (comprising eight colors or shades in all), **Figs 9e and f**. Although the Bloch project used eight colors due to its unique goals, projects typically use one to three colors. The designers, working toward a very specific design concept, created color-coded charts for the seemingly random pattern of the terra cotta tiles showing where each piece in each color of terra cotta (all of which were the same 6-inch [150 mm] tall by 4-foot-long [1.2 m] size) should be placed for each panel.

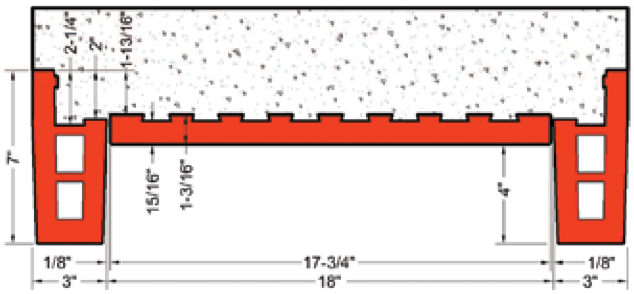
Their goal was to use the same colors throughout but overbalance the shades to make one side redder and another more buff to complement adjacent structures in those tones. There is a larger concentration of tan colors on the North elevation and a more reddish blend of colors on the West. It almost looks like a "shadow." This is one of the reasons that the architect color coded the installation instructions. They were trying to reflect the color of the traditional masonry buildings currently on campus. To the Northeast of this building there is a larger concentration of limestone/natural stone buildings, while off to the Southwest there is a larger concentration of brick buildings.

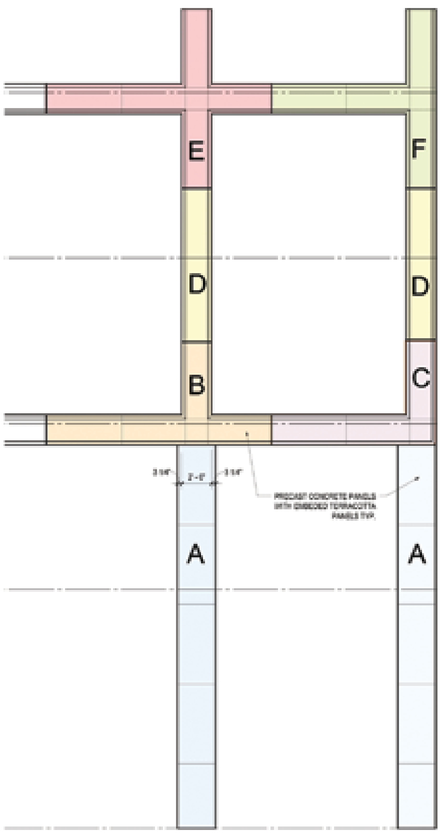
Figure 10a 1200 Seventeenth Street Office Building, Washington, D.C. Photo: Alan Schindler.

1200 Seventeenth Street Office Building, Washington, D.C.

1200 Seventeenth is an 11-story trophy class office building in the central business district of Washington, D.C., **Fig. 10a**. A richly detailed glazed terra cotta and stainless steel façade, juxtaposed against a modern glass tower, visually links two distinct neighborhoods and reflects the material palette and texture of each environment.

The building's innovative cladding system combines the ancient art of glazed terra cotta with modern, large-scale precast concrete prefabrication techniques. The design team at ZGF Architects, Washington, D.C., worked closely with the terra cotta and precast concrete manufacturers to develop and test a fabrication process that would allow the ornamental terra cotta skin to be cast integrally into large precast concrete panels. The process made





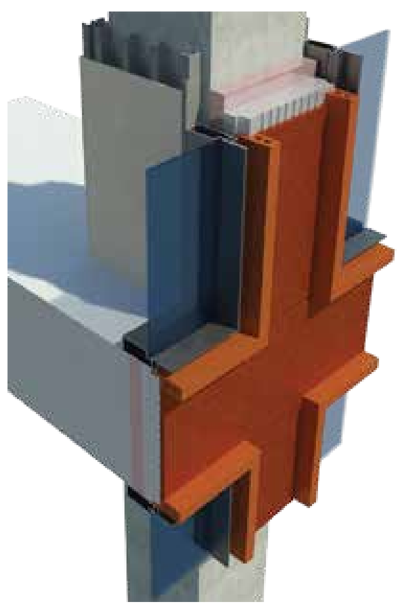


Figure 10b Framing system for façade.

it possible for exterior components to be prefabricated remotely, delivered to the site and installed on the building based on "just in time" delivery scheduling.

Once the terra cotta had satisfied the structural testing, the precaster and terra cotta supplier worked with the design team to finalize the color range for the terra cotta glaze. To minimize slight shade variations across the pieces, the design team visited the terra cotta manufacturer's facility to review the pieces before they were shipped.

The terra cotta pieces were laid in a styrofoam-lined form, glazed face down and structural backing concrete was cast on top.

The panelization plan for the north elevation shown in (**Fig. 10b**) shows that the terra cotta clad precast pieces were cross-shaped, L-shaped, upside-down-unbalanced-T shapes and small vertical sections which the team referred to as column covers. Terra cotta occurred on the north, south and east sides of the façade with precast concrete on the west side. None of the panels fit easily onto a truck for transport, and due to the fragile nature of the glazed terra cotta face, they could not be stacked or leaned against each other. Working with their trucking company, the precaster figured out a way to secure and ship four pieces at a time.

AAMC Headquarters, Washington, D.C.

The headquarters for the Association of American Medical Colleges (AAMC) is located at 655 K Street, Washington, D.C., and includes an eleven11-story office tower and four circa-1900s masonry buildings incorporated in the concrete tower structure, **Fig. 11a**. The AAMC project was designed by Shalom Baranes Associates, Washington, D.C. The tower offers nearly 290,000 square feet (2694 m^2) of open office space that provides flexibility and promotes collaboration. The exterior features multiple façades, including terra cotta-clad precast concrete panels, curtain wall, ribbon and punched windows, and metal panels, **Fig. 11b**. The project was designed to attain a Gold level LEED certification, and is one of several newer developments helping to revitalize a once neglected area of the city.

There is 23,000 square feet (2137 m^2) of precast concrete on the project, consisting of 363 panels containing nearly 5,800 pieces of 1 inch (25 mm) solid, extruded terra cotta panels in 13 different profiles and a custom ultra white color, **Fig. 11c**. In addition, one elevation has architectural precast concrete panels which had to match the terra cotta.

Terra cotta is a traditional masonry material that can be used in a contemporary way. Terra cotta can provide a distinctive, unusual appearance with a unique palette of textures and colors. Its beauty gives the designer another aesthetic choice to meet the client's priorities, preferences, and budget. Embedding terra cotta in precast concrete creates an efficient, cost-effective approach that is fast to construct and minimizes site congestion.

Figure 11a Association of American Medical Colleges (AAMC), Washington, D.C.

Figure 11b Window framing.

Figure 11c Nearly 5,800 pieces of 1 inch (25 mm) solid tiles were used in 13 different profiles and an ultra white color.

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Read the AIA Learning Units article. Note: The complete article is available at www.pci.org/elearning

Complete the online test. You will need to answer at least 80% of the questions correctly to receive the 1.0 HSW Learning Units associated with this educational program.

Learning Objectives:

After reading this article, readers will be able to:

1. Describe the design considerations for the application of terra cotta on precast concrete.
2. Explain how terra cotta is used in precast concrete.
3. Describe the benefits of using terra cotta-faced precast concrete.
4. Explain the specification and requirements when using terra cotta with precast concrete

Questions: contact Education Dept. - Alex Morales, (312) 786-0300 Email amorales@pci.org

QUESTIONS

1. Which is typically more economical?

    a. Terra cotta with rainscreens

    b. Terra cotta-faced precast concrete panels

2. Precaster and terra cotta manufacturers should be consulted early during the following:

    a. Schematic Design

    b. Design Development

    c. Construction Document

    d. Contract Administration

3. Vertical tile dimensions are more critical than horizontal dimensions when determining panelization.

    a. True

    b. False

4. What is current maximum length of solid terra cotta tiles that should be used on precast concrete?

    a. 3 feet

    b. 4 feet

    c. 5 feet

5. Thicknesses of terra cotta used with precast concrete are:

    a. 1/2 to 1 inches

    b. 3/4 to 1-1/2 inches

    c. 1 to 2 inches

6. Terra cotta can only be embedded in:

    a. Cladding panels

    b. Loadbearing panels

    c. Both a and b

7. Terra cotta tiles can be embedded in insulated precast concrete panels.

   a. True

   b. False

8. It is desirable to consider window placement depth or mullion profiles to conceal tile edges.

   a. True

   b. False

9. Tensile bond strength of terra cotta on precast concrete after freeze-thaw testing should be a minimum of:

   a. 100 psi

   b. 150 psi

   c. 200 psi

10. Terra cotta tiles are extruded and therefore require separate pieces to form rounded corners.

    a. True

    b. False